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Demonstration/Validation for Federal Specification MMM-A-121 Hazardous Air Pollutant-Free Adhesive Replacement

by Faye R. Toulan, Casey Yeary, Genie Jones, Julie Norrell, Daniel Stewart, and John J. La Scala

ARL-TR-5502 **April 2011**

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Demonstration/Validation for Federal Specification MMM-A-121 Hazardous Air Pollutant-Free Adhesive Replacement

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14. ABSTRACT

The goal of the Sustainable Painting Operations for the Total Army (SPOTA) program is to significantly reduce the amount of hazardous air pollutant (HAP) emissions produced in coating operations, including adhesives application and removal. Adhesives and sealants account for ~5% of U.S. Army-wide HAP emissions from surface coating operations. Materials conforming to Federal specification MMM-A-121 have been identified as one of the largest contributors. Identifying a HAP-free adhesive that conforms to MMM-A-121 is a high priority for the Army. The purpose of this research is to demonstrate and validate the HAP-free alternative adhesive 3M-847 in place of the baseline materials 3M-1357 and Clifton E-1293 adhesive for specification MMM-A-121. Based on 2003 data, switching from the baseline Clifton E-1293 or 3M-1357 to the alternative 3M-847 would mean an Army-wide reduction of over 1000 lb/year of HAP emissions. This report details the methods for field testing adhesive on an aviation helmet (model no. HGU-56/P) "edge beading" preventative maintenance/repair, an Army UH-60 Blackhawk helicopter "nose door seal," and for general Army use conducted at Lowe Army Heliport, Fort Rucker, AL. Furthermore, this report details the identification and solution of several previously undocumented issues associated with substrate materials currently used by the Army, resulting in modified adhesive application procedures and updated laboratory tests related to the MMM-A-121 specification.

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1. Introduction

The Environmental Protection Agency (EPA) is planning to propose the Defense Land Systems and Miscellaneous Equipment (DLSME) National Emission Standard for Hazardous Air Pollutants (NESHAP) that will affect U.S. Army surface coating operations (*1*). The materials used for coating operations at many U.S. Army installations were surveyed, and it was determined that the Army used numerous adhesives and sealants, among other coating materials, that contain significant amounts of hazardous air pollutants (HAPs). The Army has determined that it is more cost-effective to reduce or eliminate HAPs from coating formulations rather than using emissions control devices to capture and treat them (*2*). Therefore, the goal of the Sustainable Painting Operations for the Total Army program is to significantly reduce the amount of HAP emissions produced in coating operations, including adhesives and sealant application and removal. Adhesives and sealants account for ~5% of Army-wide HAP emissions from surface coating operations. Based on 2003 data (*3*), materials conforming to Federal specification MMM-A-121 (*2*) have been identified as one of the largest contributors. Two of the most commonly used baseline products qualified under the MMM-A-121 specification are Clifton Adhesive E-1293, which contains approximately 50–60 weight-percent HAP (*4*), and 3M Scotch-Weld* 1357, which contains ~16–19 weight-percent HAP (*5*). As a result, identifying a HAP-free adhesive that conforms to MMM-A-121 is a high priority for the Army.

Various laboratory tests were conducted to determine the relative similarity of the baseline products to the potential alternative materials (*6*). This testing included nonvolatile solids content, rheology, dry time, and adhesion strength. In particular, adhesion studies involved neoprene rubber, styrene-butadiene rubber (SBR), and nitrile rubber bonded to unpolished steel as specified in MMM-A-121 (*6*). Several adhesive products were tested, but only one adhesive met the requirements of MMM-A-121. 3M-847, containing the carrier solvent acetone, was identified as an acceptable HAP-free replacement for MMM-A-121 adhesives such as Clifton E-1293 and 3M-1357. Acetone is listed as an exempt volatile organic compound (VOC) and not a HAP by the EPA (*2*). 3M-847 passed all variations of strip adhesion testing as required in the MMM-A-121 specification.

The purpose of this research is to demonstrate and validate the HAP-free alternative adhesive 3M-847 in place of the baseline materials 3M-1357 and Clifton E-1293 adhesive for MMM-A-121. Switching from the current baseline materials Clifton E-1293 or 3M-1357 to the HAP-free adhesive alternative 3M-847 would mean an Army-wide reduction of over 1000 lb/year of HAP emissions based on 2003 data (*6*). However, to approve 3M-847 for military use, a demonstration /validation field trial at an Army facility was necessary. This report details methods for

*3M Scotch-Weld is a trademark of 3M Company.

demonstrating and validating 3M-847 adhesive on an HGU-56/P aviation helmet and a UH-60 Blackhawk helicopter (figure 1), conducted at Lowe Army Heliport Fort Rucker, AL. Specifically, this HAP-free product was demonstrated/validated on aviation helmet model no. HGU-56/P "edge beading" preventative maintenance/repair (figure 2), a UH-60 Blackhawk helicopter "nose door seal" (NDS) (figure 3), and for general Army use. Furthermore, this report details the identification and solution of several previously undocumented issues associated with substrate materials currently used by the Army, resulting in modified adhesive application procedures and updated laboratory tests related to the MMM-A-121 specification.

Figure 1. UH-60 Blackhawk helicopter (left) and HGU-56/P aviation helmet (right).

Figure 2. HGU-56/P aviation helmet without beading (left) and with beading (right).

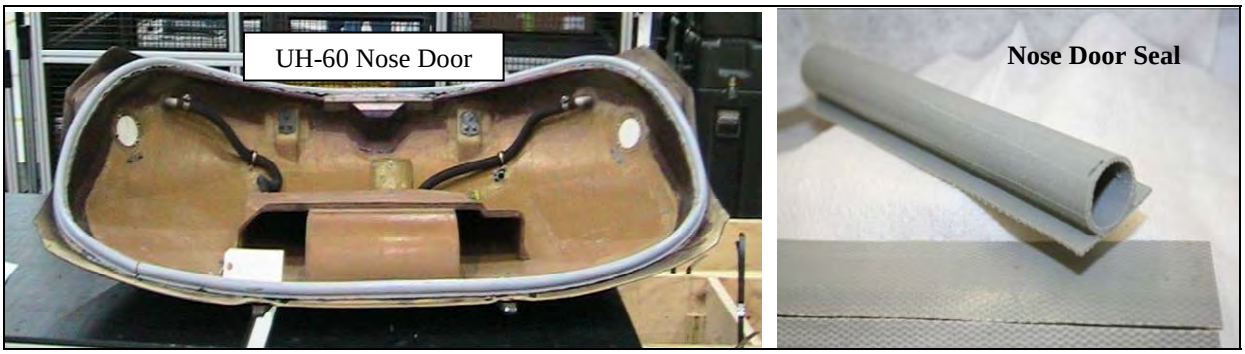

Figure 3. UH-60 nose door with NDS bonded (left) and UH-60 NDS unbonded (right).

1.1 Materials

Table 1 shows a summary of physical properties for the adhesives included in this test series. All of the information listed in table 1 was assembled from the material safety data sheet (MSDS) and technical data sheet for each of the three adhesive products. There are two baseline adhesives taken from the qualified product list (QPL) and one HAP-free alternative.

Table 1. Physical properties of adhesives in test series (*4, 5, 7–10*).

Product Name	HAP (wt. %)	VOC (g/L)	Solvents	Polymer Base	Density (lb/gal)	Solids (%)
Clifton E-1293 (baseline helmet)	50–60	~660	Toluene, hexane, MEK, and acetone	Polychloroprene	6.5–6.9	17–19
3M-1357 (baseline UH-60)	16–19	~490	Petroleum distillate, acetone, MEK, toluene, and hexane	Polychloroprene	6.6–7.0	23–27
3M-847 (alternative helmet and UH-60)	0	0	Acetone	Nitrile rubber	7.4–7.8	33–39

Note: MEK = methyl ethyl ketone.

Baseline Clifton E-1293 adhesive is designed for bonding vulcanized synthetic rubber gaskets, matting, and similar items to steel. It will adhere to neoprene, SBR, and nitrile gasketing (*9*). This product may be used as a general-purpose, water-resistant, contact cement where rapid and aggressive bonds are required (*9*). Clifton E-1293 adhesive meets the requirements of MMM-A-121 and contains 50%–60% HAPs (*4*, *9*).

Baseline 3M Scotch-Weld 1357 neoprene high-performance contact adhesive (3M-1357) can be used to bond most rubber, cloth, metal, wood, foamed glass, paper honeycomb, decorative plastic laminates, and many other substrates (*7*). Some key features of this product are long bonding range, excellent initial strength, and high heat resistance. It meets the specification requirements of MMM-A-121 and contains 16%–19% HAPs (*5*, *7*).

Alternative 3M Scotch-Weld 847 nitrile high-performance rubber and gasket adhesives (3M-847) is a medium-viscosity-grade adhesive that provides strong flexible bonds for many brush or

flow applications (*10*). 3M-847 is quick drying, has excellent resistance to many fuels and oils, and bonds leather, nitrile rubber, most plastics, and gasketing materials to a variety of substrates. This product has previously been qualified to meet the requirements of MIL-C-4003 (canceled) and contains 0% HAPs (*8*, *10*).

2. Field Trial Conducted 31 March 2009

2.1 Demonstration/Validation on the Edge Beading for an HGU/P56 Aviation Helmet

A demonstration/validation plan was written for the replacement of edge beading on aviation helmet model no. HGU/56/P to compare the baseline adhesive 3M-1357 and the HAP-free 3M-847 (appendix A). The helmet repair demonstration/validation was performed on 31 March 2009 at the U.S. Army Aviation Center Logistics Command (ACLC) Repair Shop, Lowe Army Heliport, Fort Rucker, AL. Two aviation helmets were selected for concurrent demonstration /validation. Helmet ID no. G3660 used the baseline adhesive 3M-1357, and helmet ID no. B0985 used the HAP-free adhesive 3M-847. The old adhesive and edge beading (*11*) were removed from the helmets. The helmet surface was wiped clean, removing any old adhesive. One coat of new adhesive was applied by brush to both the edge beading and the perimeter of the helmet shell. Figure 4 shows a photograph of the new helmet edge beading (*11*) wrapped around a wooden stick with one coat of freshly applied adhesive. Once aggressively tacky, the adhesive coated edge beading was then unrolled onto the perimeter of the helmet shell.

Figure 4. Adhesive application for aviation helmet.

The edge beading repair adhesive performance characteristics were required to be equal to or better than the baseline. The helmets were evaluated by the inspector for blistering, edge lifting, deterioration of adhesive, or failure of the adhesive bond (*12*). The evaluations were conducted at the time of application—24 h, 90 days, and 180 days after the initial application (appendix A). Technicians evaluated the ease of adhesive application and performance of initial bonding relative to the baseline at the time of initial application. The technician commented that the initial application of the 3M-847 adhesive was slightly harder to work with compared to the

baseline 3M-1357 due to higher viscosity and faster solvent evaporation. However, this was the technician's first time working with either adhesive. The 24-h inspection showed no significant differences between the two adhesives.

During the field trial, we discovered a number of issues with the demonstration/validation plan. First, we found that the edge beading repair is normally performed using Clifton E-1293 instead of 3M-1357. Both adhesives are on the QPL for MMM-A-121. However, the E-1293 baseline was not part of the laboratory testing conducted prior to the 31 March 2009 demonstration /validation. Also, the technicians were not familiar with the baseline 3M-1357 and the performance characteristics relative to the Clifton E-1293 (table 1). The second major issue with the 31 March 2009 demonstration/validation was the aviation helmet shell, which is a hybrid composite material made from Spectra* and graphite in an epoxy matrix (*13*). Composites tend to be highly porous relative to unpolished steel, which is the requisite rigid substrate described in MMM-A-121. Higher substrate porosity could negatively affect adhesion performance if the adhesive is not applied sufficiently. On the other hand, the edge beading was described in the military specification MIL-R-6855 (*11*) as molded synthetic rubber/elastomer, Class 2, Type B, Grade 40. This beading is similar to the rubber compounds specified in MMM-A-121 and, thus, poses no issues. This demonstration/validation was discontinued after 7 days due to composition of the HGU/P56 helmet shell and the different baseline adhesive Clifton E-1293.

2.2 Demonstration/Validation on the Nose Door Seal of a UH-60 Blackhawk

A "Demonstration/Validation Plan for MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel HAP Free Replacement" was written for the field trial conducted on 31 March 2009 at Lowe Army Heliport (appendix A). The nose door seal (ZZ-R-765) was bonded to the inner perimeter of a UH-60 Blackhawk helicopter nose door. Two UH-60 Blackhawk helicopters were selected for concurrent field testing. The first aircraft (tail no. 4577) used the baseline adhesive 3M-1357 and the second aircraft (tail no. 4571) used HAP-free adhesive 3M-847. The UH-60 nose door (figure 3) was detached from the body of the helicopter in order to remove the NDS, clean and prepare the nose door surface, and apply the new adhesive as specified in technical manual procedure TM-1-1520-237-23 (*14*). The inner perimeter of the UH-60 nose door was lightly sanded with an abrasive paper and cleaned with acetone prior to the adhesive application. One coat of adhesive was applied by brush (~12 in intervals) to the entire inner perimeter (~1 in wide) of the nose door. The NDS was roughened with abrasive paper and cleaned with acetone to prepare for adhesive application. Figure 5 illustrates installation and a cross section of the NDS. One coat of adhesive was applied by brush (~12-in intervals) to the NDS and bonded to the UH-60 nose door (figure 6, left). Clamps were used (~8-in intervals) after the initial adhesive application to keep the NDS seal in place (figure 6, right).

*Spectra is a trademark of SPECTRA Anaheim.

REPLACE NOSE DOOR RAIN GUTTER SEAL - Continued

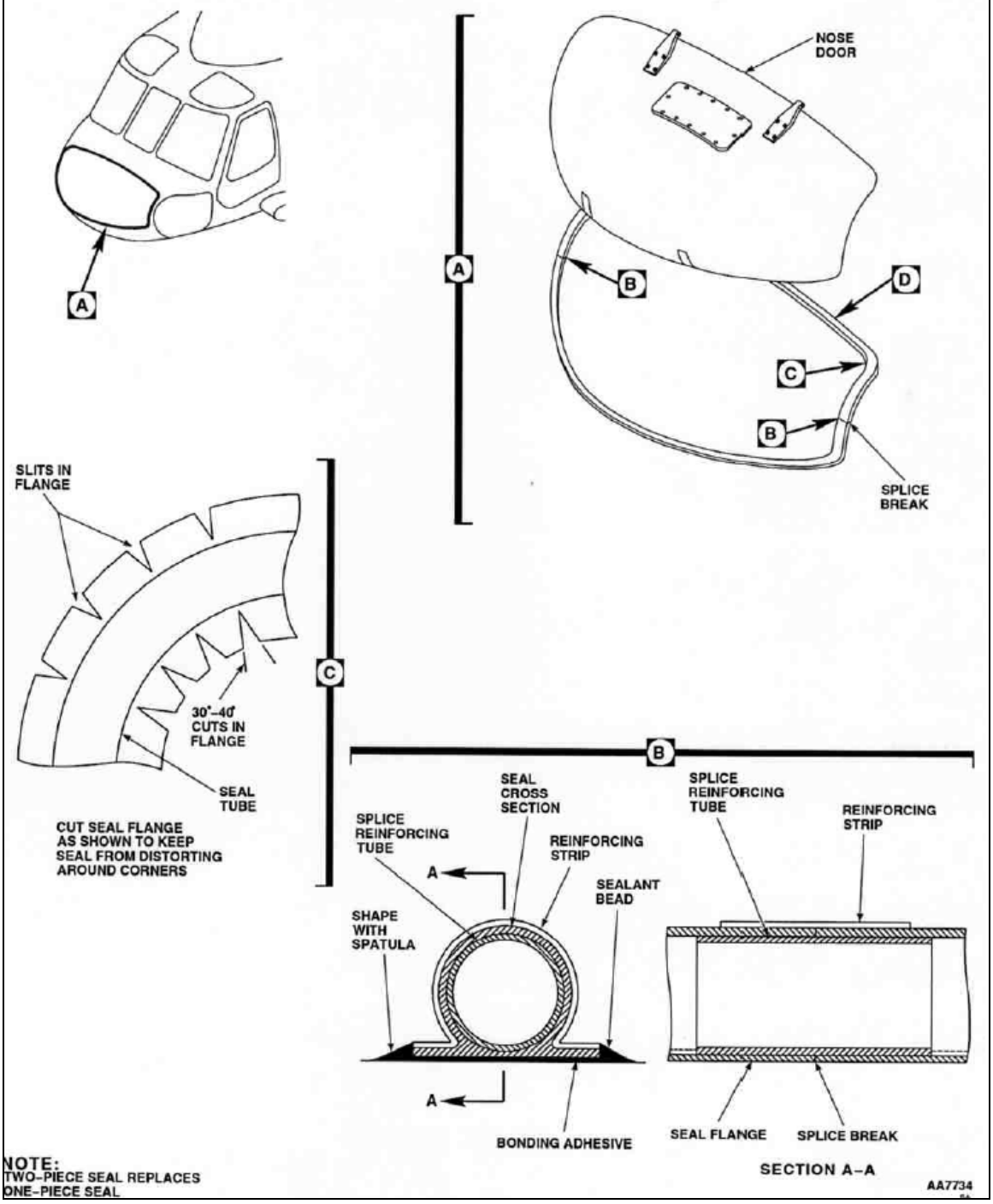

Figure 5. UH-60 nose door seal replacement illustration.

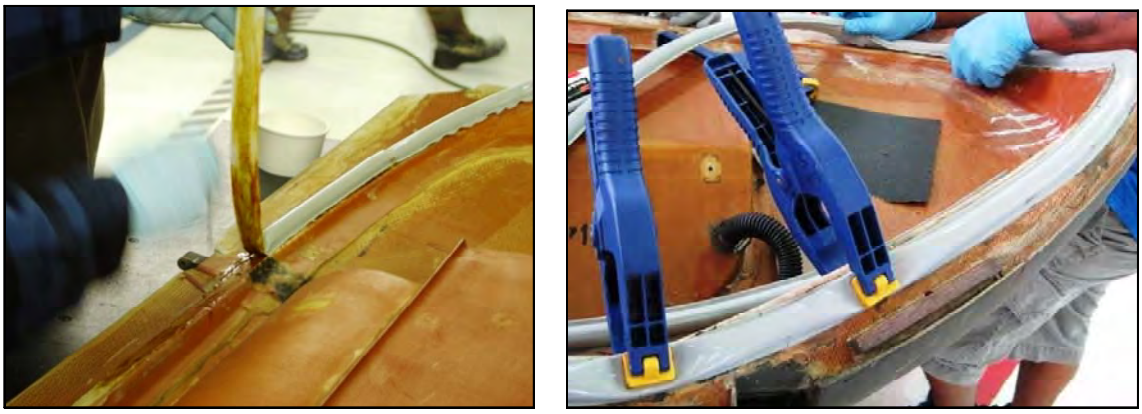

Figure 6. Application of adhesive to UH-60 nose door (left) and NDS installation (right).

The NDS HAP-free adhesive performance was required to be equal to or better than the baseline. The UH-60 NDS was evaluated at the adhesive interface by the inspector for blistering, edge lifting, deterioration of adhesive, or failure of the adhesive bond (*12*). The evaluations were conducted at the time of application—24 h, 7 days, 30 days, and 90 days after initial application (appendix A). Technicians evaluated the ease of adhesive application and performance of the HAP-free (3M-847) initial bonding relative to the baseline (3M-1357) at the time of the initial application. The technician commented that the initial application of the 3M-847 adhesive was slightly harder to work with compared to the baseline 3M-1357 because of the higher viscosity and faster solvent evaporation. The 24-h inspection showed no significant differences between the two adhesives. However, on 7 April 2009, both the baseline (3M-1357) and HAP-free adhesive (3M-847) exhibited significant failure on the UH-60 helicopter NDS (figure 7). In addition to edge lifting seen in the figure 7 photographs, both adhesives also exhibited legging. (Legging is the drawing of filaments or strings when adhesive bonded substrates are separated [*12*]). Due to the failure captured in figure 7, Lowe Army Heliport technicians removed the NDS from both Blackhawk helicopters and thus ended the demonstration/validation at that time.

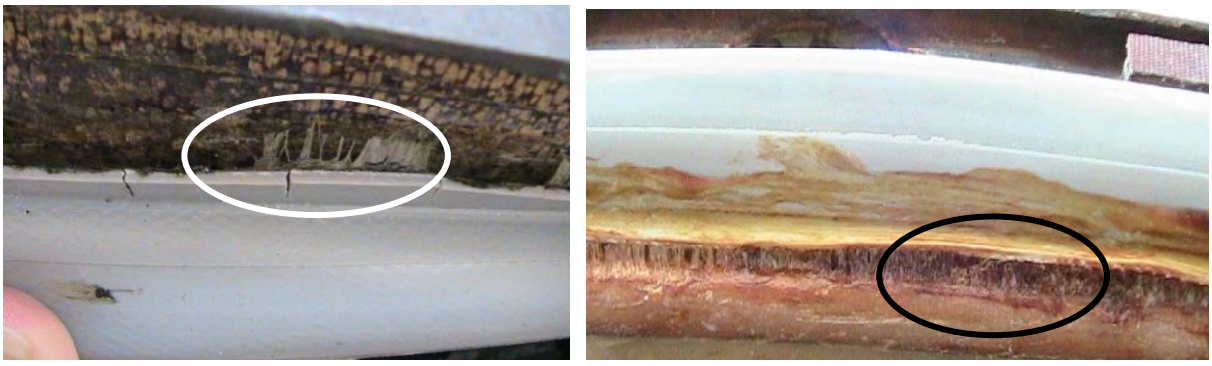

Figure 7. Edge lifting 3M-1357 (left) and 3M-847 (right).

During the field trial, we discovered a number of issues with the demonstration/validation plan. First, the UH-60 helicopter NDS was made of silicone rubber (ZZ-R-765, Class 3B, and Grade 50). Class 3B was tear and flex resistant, and Grade 50 corresponded to the nominal shore-A-durometer hardness value (*15*). MMM-A-121 specified only three kinds of rubber substrates, consisting of neoprene, SBR, or nitrile (*16*). Second, the UH-60 helicopter nose door was constructed of a lightweight composite material which was highly porous, whereas MMM-A-121 specified a low-porosity metal substrate such as unpolished steel (figure 8). Furthermore, only a single layer of adhesive was applied per substrate. Higher substrate porosity could negatively affect adhesion performance if the adhesive is not applied sufficiently.

Figure 8. UH-60 composite nose door.

2.3 Recommendations From the Field Trial Conducted 31 March 2009

On 17 April 2009, the Environmental Technology Integration Group, U.S. Army Aviation and Missile Command (AMCOM) determined that the field test failure was related to the procedure for application and not the adhesive formulation because the failure occurred in both the baseline and replacement adhesives. Based on the unexpected failures of both adhesives, a new demonstration/validation was required, with a new adhesive application procedure defined. The findings from the first demonstration/validation indicated that a number of modifications to the demonstration/validation plan and additional experimentation were necessary. The Clifton E-1293 adhesive should be added to the test series for comparison. In addition to the adhesive, substrates similar in composition to the UH-60 nose door, NDS, and HGU/P56 aviation helmet were also needed for testing. Evaluation of the adhesive bond strength using one coat of adhesive per substrate compared to using two coats of adhesive per substrate was included as an application procedure change.

3. Laboratory Testing

A new series of lab tests were required after the 31 March 2009 demonstration/validation resulted in the discoveries that both the nose door and NDS of the UH-60 helicopter were not constructed of the requisite materials according to MMM-A-121. The lab testing described in ARL-TR-4715 (*6*) used the requisite substrates of unpolished steel panels and one of three kinds of vulcanized rubber compounds (neoprene, SBR, and nitrile). However, the UH-60 helicopter nose door and the HGU/P56 aviation helmet are made of lightweight composite materials, which have a porous surface instead of the low-porosity surface of unpolished steel (figure 8). Because of the porosity differences of the field trial substrates compared to the MMM-A-121 requisite substrate materials, we hypothesized that the adhesive was absorbed into the substrate, leaving an insufficient amount of product for bonding on the surfaces. A second coat of adhesive should allow for better bonding of the two surfaces. The following experiments seek to show that the high porosity of the composite substrate requires application of additional coats of adhesive to achieve a proper bond.

In addition, the NDS (ZZ-R-765) is made of silicone rubber; however, MMM-A-121 specified neoprene, SBR, or nitrile rubber compounds (*15*). Since the silicone rubber was not listed on the MMM-A-121 specification, it was not included as a substrate material in the original test series. Because the silicone rubber was not tested in the lab, there was no means to determine the bonding performance of the adhesives on this substrate in the original test series. Furthermore, the technicians at Fort Rucker have typically used the baseline adhesive Clifton E-1293 on the edge beading repair of the aviation helmets, not the baseline 3M-1357. The Clifton E-1293 adhesive was not part of the original lab test series because the use of Clifton E-1293 was unknown. The following experiments examine the performance of 3M-847 relative to 3M-1357 and Clifton E-1293 on silicone rubber bonded to composite to more accurately assess the performance of the replacement adhesive.

3.1 Materials and Substrate Preparation

An Instron peel test (ASTM D 429-03) was used to quantify the adhesive strength of all the adhesive products (*17*). To better simulate the adhesive behavior observed in the March 2009 demonstration/validation, genuine UH-60 NDS was adhered to a fiberglass composite panel (figure 9). Huntsman 8603 epoxy resin reinforced with S-2 fabric was used. The S-2 glass fabric was a 24 oz/yd^2, 5 × 5 woven roving plain weave, with a standard 463 sizing. This 463 sizing is compatible with epoxies, polyesters, and phenolic resin systems. The S-2 glass fiber, produced by AGY, was converted into a fabric by Burlington Glass Fabrics Industries, Inc. Vacuum-assisted resin transfer molding was used to fabricate the composite test panels (*18*). The composite panels were 8-plies thick. The composite panel thickness was ~5 mm, and the fiber volume fraction was ~50%. Peel assemblies were prepared using a 3- × 6- × 0.25-in

composite panel and a 1- × 6-in strip of UH-60 NDS (ZZ-R-765, Class 3B, and Grade 50). The contact surface of the NDS was hand-sanded with a course abrasive paper to roughen the bonding area and cleaned with acetone (appendix A). The rough side of the composite panel was used for bonding to simulate the rough texture of the interior of the UH-60 nose door. Release tape was placed on both substrates to create a clean edge to start the peel ~2 in from the top of the panel (figure 9). The adhesives included in this test series were 3M-1357, Clifton E-1293, and 3M-847 (table 1). Peel assemblies were prepared both with one coat of adhesive per substrate and with two coats of adhesive per substrate. Peel assemblies with two coats of adhesive per substrate were allowed to dry between coats. Adhesive was applied with a brush to achieve a thin uniform coat. Once the adhesive had dried to a tacky consistency, the two substrates were bonded together. A roller 2 inches in diameter was used to remove any trapped air between the substrates and assist with the bonding process.

Figure 9. Composite panel and UH-60 NDS.

Samples were also prepared using the MMM-A-121 prescribed substrate combination of unpolished steel and neoprene rubber as a baseline (figure 10). The neoprene (1 × 6 × 0.025 in) was hand-sanded using a course abrasive paper to roughen the bonding surface and cleaned with acetone. The steel (3 × 6 × 0.032 in) was cleaned with acetone prior to adhesive application. Release tape was placed on both substrates to create a clean edge to start the peel ~2 in from the top of the panel (figure 10). This substrate combination was used to test 3M-1357, Clifton E-1293, and 3M-847 adhesives. The product was applied with a brush until a thin uniform film was achieved. Two coats of adhesive (allowing drying between coats) were required on the rubber substrate and one coat on the steel. The steel substrate required just one coat of adhesive because of the low porosity, whereas the rubber substrate required two coats of adhesive because of the higher porosity of the material. The assemblies were conditioned at room temperature for 6 days prior to peel adhesion testing (*16*).

Figure 10. Unpolished steel and neoprene substrates.

3.2 Peel Test Method

ASTM D 429-03, "Standard Test Methods for Rubber Property-Adhesion to Rigid Substrates: Method B-90° Stripping Test-Rubber Part Assembled to One Metal Plate," (*17*) was used as a guideline for this test method to determine the peel strengths of the UH-60 nose door seal to composite panel. Peel strength is the average load per unit width of bond-line required to progressively separate a flexible member from a rigid member or another flexible member. Testing was conducted on an Instron model 1123, a power-driven machine capable of uniform expansion between the grips. The test machine digitally measured the load applied and the extension to the rubber strip during the 90° angle peel. The head of the machine was set to travel 2 ± 0.2 in/min. The top grip was a hydraulic clamp used to hold the free end (~2 × 1 in) of the rubber substrate bonded to the panel during testing. The hydraulic clamp provides constant pressure to keep the rubber substrate in the grip. The bottom grip of the Instron was a table mounted on linear bearings. The linear bearings of the table allowed forward movement while the rubber strip was peeled from the composite panel and remained perpendicular to the panel. The composite panel was affixed to the table mount located on the bottom grip (figure 11).

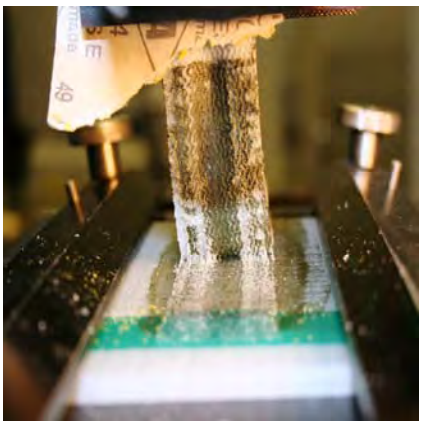

Figure 11. Peel adhesion test.

3.3 Results of the 90° Peel Test

Figure 12 shows the peel strength for both baseline products and the HAP-free alternative applied to the substrate combination of unpolished steel bonded to neoprene rubber. All three adhesives met the minimum MMM-A-121 peel strength requirement of 5 lbf with the steel-to-neoprene substrate combination. The baseline 3M-1357 had the highest peel strength of ~11 lbf, followed by Clifton E-1293, with a peel strength of ~9.5 lbf, and 3M-847 had the lowest peel strength of ~7.5 lbf. Despite the slightly lower peel strength, the results suggested that HAP-free 3M-847 was a suitable alternative for MMM-A-121 if used on the traditional substrate combination of steel and rubber. The data in figure 12 also supports the original test results described in TR-4715 for 3M-1357 and 3M-847 (*6*).

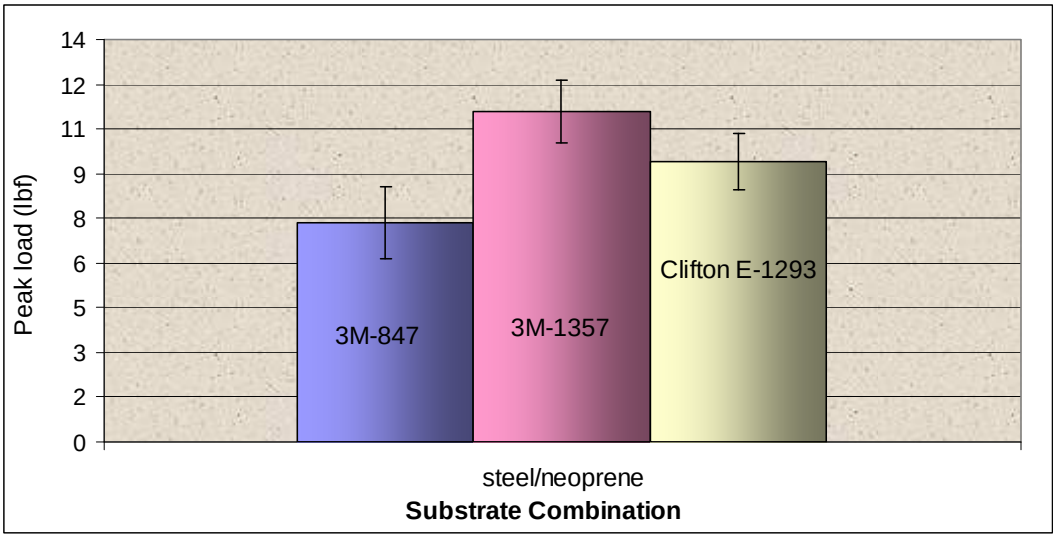

Figure 12. Steel bonded to neoprene peel results.

A comparison of one coat of adhesive applied to both substrates (composite/NDS) and two coats of adhesive applied to both substrates is captured in figure 13. 3M-847 had a peel strength of ~17 lbf, with one coat of adhesive per substrate compared to 3M-1357 (baseline), which had a peel strength of ~8 lbf. The peel strength for both products increased considerably with two coats of adhesive per substrate. The peel strength for HAP-free 3M-847 increased to ~27 lbf, and the baseline 3M-1357 increased to ~18 lbf. The 90° peel results for the composite/NDS substrate combination were significantly different than the steel/neoprene combination. The HAP-free 3M-847 performed better than the baseline 3M-1357 on the composite/NDS substrate combination regardless of the number of coats. The lab testing suggested that the porosity of substrate materials, composition of materials, and number of adhesive coats could affect the product's performance. The next step was to conduct another field trial to validate these laboratory findings.

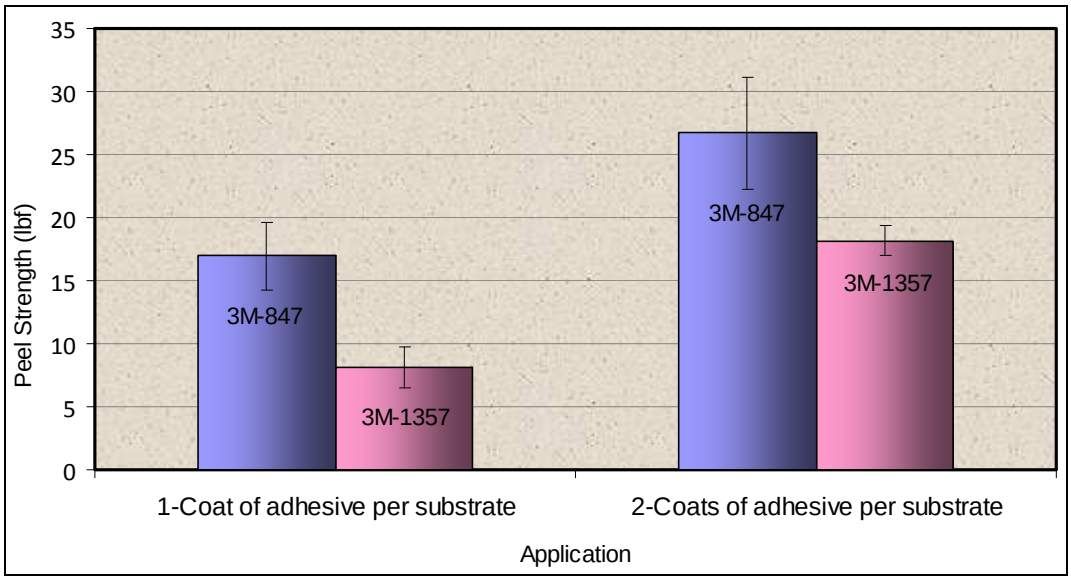

Figure 13. Composite bonded to NDS peel results.

4. Field Trial Conducted 30 July 2009

On 29 July 2009, in conjunction with the U.S. Army Research Laboratory (ARL) and AMCOM G-4 team, the ACLC Environmental Group executed the ARL "Demonstration/Validation Plan II For MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel, HAP Free Replacement" (appendix B) at Lowe Army Heliport (appendix C). The purpose of this demonstration/validation was to determine if the HAP-free rubber and gasket adhesive alternative (3M Scotch-Weld 847) could be substituted for the baseline material (3M Scotch-Weld 1357 and Clifton adhesive E-1293) for MMM-A-121 adhesive on an Army UH-60 Blackhawk helicopter nose door seal, HGU-56/P aviation helmet preventative maintenance/ repair, and for general Army use. Simultaneous tests were conducted on a UH-60 helicopter nose door seal and HGU-56/P aviation helmet edge beading. A baseline was used in each test so that the HAP-free alternate (3M-847) could be assessed in real time with the adhesive used currently. The baseline for the UH-60 nose door seal was 3M-1357, and the baseline for the helmet edge beading was Clifton E-1293. Teams were used to apply the baseline and alternative on two UH-60 nose door seals, one for the baseline (tail no. 4633) and one for the alternate (tail no. 4441) (appendix B). Both teams closely followed the demonstration/validation plan (appendix B) that outlined the proper way to apply each adhesive, ensuring that two coats of adhesive per substrate were applied for each product, as the photos in figures 14 and 15 illustrate. This application directive was vital for the success of the field trial. Comments from the alternative adhesive team spoke of the tackiness of the new adhesive and the shorter drying time

Figure 14. Baseline (3M-1357) adhesive application to UH-60 NDS.

Figure 15. Alternative (3M-847) adhesive application to UH-60 NDS.

both of which contributed to the difficulty in spreading the material evenly. Overall, the team stated the alternative adhesive (3M-847) appeared to perform well but was slightly more difficult to apply than the baseline (3M-1357).

After the adhesive application, the nose doors were reinstalled on the aircraft (figure 16) and released into the field for normal operation. Inspections were conducted at 24 h, 7 days, 30 days, and 90 days after application to determine how the adhesives performed over time (appendix B). In each inspection, the alternative adhesive did not show any signs of slippage, delamination,

blistering, deterioration, or failure compared to the baseline (appendix B). The photos in figure 16 show the two UH-60 helicopters after 90 days in the field. The helicopters were photographed intentionally with the nose door open to view the condition of the NDS. At the end of the 90 day field trial, both NDS's were still properly adhered to the respective UH-60 nose door. Overall, the inspector concluded that the alternative adhesive (3M-847) performed as well as the baseline (3M-1357).

Figure 16. UH-60 NDS after 90 days in the field, baseline (left) and alternate (right).

One technician applied the baseline Clifton E-1293 (helmet ID no. R20048) and the alternative 3M-847 (helmet ID no. L284) to two HGU-56/P aviation helmets to secure the edge beading (appendix B). The technician closely followed the demonstration/validation plan that outlined the proper procedure for the application of the adhesives (appendix B). Applying two coats of adhesive per substrate was a key change from the first demonstration/validation (March 2009) and the second demonstration/validation (July 2009). Comments from the technician indicated that the alternative 3M-847 dried faster than the baseline, causing the edge beading to look sloppy and pucker in the curved areas (figure 17). Overall, the technician preferred the baseline adhesive (E-1293) to the alternative (3M-847) because of the ease of application. Once the adhesive application was completed, the helmets were released to the field for normal operation.

Figure 17. Aviation helmet after adhesive application, baseline (left) and alternate (right).

Inspections were conducted at 24 h, 90 days, and 180 days after adhesive application to determine how the products performed over time (appendix B). In each inspection, the alternative adhesive did not show any signs of slippage, delamination, blistering, deterioration, or failure, except for a slight lifting in the curved areas (appendix B). This lifting appeared to be caused by the fast drying time during application rather than failure of the adhesive over time (figure 18). Overall, the inspector concluded that the alternative adhesive (3M-847) worked as well as the baseline (E-1293) if the quick drying time was considered in the application process.

Figure 18. Aviation helmet after 180 days in the field, baseline (left) and alternate (right).

5. Conclusions

5.1 HGU-56/P Aviation Helmet Edge Beading

The first demonstration/validation conducted on 31 March 2009 revealed that Clifton E-1293 adhesive was the MMM-A-121 baseline currently used on the HGU-56/P aviation helmets edge beading and not 3M-1357, as originally thought. Additionally, the field trial revealed that the aviation helmet was constructed of a lightweight composite material and not the requisite MMM-A-121 low–porosity, unpolished steel. Lab tests showed the baseline E-1293 performed slightly better relative to the alternative 3M-847. The second field trial verified that HAP-free 3M-847 had a similar performance relative to the baseline E-1293 when bonding the rubber edge beading to the perimeter of the HGU-56/P aviation helmet and was a suitable MMM-A-121 replacement.

5.2 UH-60 Blackhawk Helicopter Nose Door Seal

The first demonstration/validation revealed that the UH-60 substrates were not the traditional rubber compounds (SBR, neoprene, or nitrile) bonded to unpolished steel specified in MMM-A-121 but rather a silicone rubber NDS bonded to a lightweight composite nose door. A single coat of adhesive per substrate was insufficient for proper bonding when applied to porous substrates. Additional laboratory testing with genuine substrate materials used by the Army

confirmed that bond strength of all adhesives significantly increased when two coats of adhesive per substrate were applied. Furthermore, the 3M-847 HAP-free adhesive demonstrated greater bond strength in laboratory testing than the baseline 3M-1357 on the target substrates. The second field trial confirmed the laboratory test results and the suitability of HAP free 3M-847 adhesive as an alternative to the MMM-A-121 baseline 3M-1357 for bonding the silicone rubber NDS to the inner perimeter of the UH-60 Blackhawk nose door.

6. References

1. Concurrent Technologies Corporation. *NESHAP Requirements Assessment for Miscellaneous Coatings, Adhesives, Sealers, Etc*.; Sustainable Paint Operations for the Total Army; Johnstown, PA, 2004.
2. Vallone, J. *NESHAP Requirements Assessment for Miscellaneous Coatings, Adhesives, Sealers, Etc*.; Sustainable Painting Operations for the Total Army; Johnstown, PA, 2004.
3. Concurrent Technologies Corporation. *Addendum to Final Potential Alternatives Report*; Sustainable Painting Operations for the Total Army: Johnstown, PA, 2006.
4. Clifton Adhesive, Inc. E-1293 Adhesive MSDS; Wayne, NJ, March 1990.
5. 3M Company. 3M Scotch-Weld High Neoprene Performance Contact Adhesive 1357 MSDS; St. Paul, MN, November 2006.
6. Toulan, F. R. *MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel HAP-Free Replacement*; ARL-TR-4715; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, February 2009.
7. 3M Company. 3M Scotch-Weld Neoprene High Performance Contact Adhesive 1357 Technical Data Sheet; St. Paul, MN, November 2006.
8. 3M Company. 3M Scotch-Weld Nitrile High Performance Rubber and Gasket Adhesive 847 MSDS; St. Paul, MN, November 2007.
9. Clifton Adhesive, Inc. E-1293 Adhesive Technical Data Sheet; Wayne, NJ, April 2007.
10. 3M Company. 3M Scotch-Weld Nitrile High Performance Rubber and Gasket Adhesive 847 Technical Data Sheet; St. Paul, MN, November 2007.
11. MIL-R-6855. *Sheet, Rubber, Synthetic, Special Shape, Extruded* **1987**.
12. ASTM 907 05. Standard Terminology of Adhesives. *Annu. Book ASTM Stand.* **2005**.
13. Gentex Corporation. HGU56/P Helmet Systems Technical Data Sheet; Carbondale, PA, 2006.
14. TM-1-1520-237-23. Technical Manual for Replacement of Nose Door Seals on UH-60 Blackhawk Helicopters, 20 June 2003.
15. Federal Specification ZZ-R 765E/GEN. *Rubber Silicone (General Specification)*; U.S. Government Printing Office, Washington, DC, 20 December **1991**.

16. MMM-A-121. *Adhesive, Bonding Vulcanized Synthetic Rubber to Steel*; U.S. Government Printing Office, Washington, DC, December **1966**.

17. ASTM D 429-03. Standard Test Methods for Rubber Property-Adhesion to Rigid Substrates: Method B-90° Stripping Test-Rubber Part Assembled to One Metal Plate. *Annu. Book ASTM Stand.* **2003**.

18. Rigas, E. J.; Mulkern, T. J.; Walsh, S. M.; Nguyen, S. P. *Effects of Processing Conditions on Vacuum Assisted Resin Transfer Molding Process (VARTM)*; ARL-TR-2480; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2001.

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Appendix A. Demonstration/Validation Plan (Original) for MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel HAP-Free Replacement [1]

This appendix appears in its original form, without editorial change.

[1]Toulan, F. R. Demonstration Validation Plan (Original) for MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel HAP-Free Replacement. U. S. Army Research Laboratory: Aberdeen Proving Ground, MD, March 2009.

ARMY RESEARCH LABORATORY

Demonstration/Validation Plan (Original)

For

MMM-A-121 Federal Specification
Adhesive, Bonding Vulcanized Synthetic Rubber to Steel
HAP Free Replacement

Demonstration Site: Lowe Airfield at Fort Rucker, AL

Purpose: To demonstrate/validate a HAP-free rubber & gasket adhesive alternative (*3M Scotch-Weld™ 847*) in place of baseline material (*3M Scotch-Weld™ 1357*) for federal specification MMM-A-121 adhesive bonding vulcanized synthetic rubber to steel on an Army UH-60 (Blackhawk) helicopter "nose door seal", aviation helmet (model #HGU-56/P) preventative maintenance/repair, and for general Army use through the Sustainable Painting Operations for the Total Army (SPOTA) Program.

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1.0 INTRODUCTION

The Environmental Protection Agency (EPA) is in the process of mandating the Defense Land Systems and Miscellaneous Equipment (DLSME) National Emission Standard for Hazardous Air Pollutants (NESHAP) that will affect Army surface coating operations [1]. The materials used for coatings operations at many Army installations was surveyed, and it was found that the Army uses numerous adhesives and sealants among other coating materials that contain significant amounts of hazardous air pollutants (HAP) [1]. The Army has determined that it is more cost-effective to reduce or eliminate HAP emissions from coatings operations rather than using emissions control devices to capture and treat them [2]. Therefore, the goal of the Sustainable Painting Operations for the Total Army (SPOTA) program is to severely reduce the amount of HAP emissions produced in coatings operations, including adhesives and sealant application and removal.

Army adhesives and sealants account for 10% of the Army's surface coating materials and 5% of the total HAP emissions. Materials conforming to MMM-A-121 produce over 20% of the HAPs from Army adhesives and sealants. The most commonly used baseline products under the MMM-A-121 specification are 3M-1357 Scotch-Weld™ Neoprene High Performance Contact Adhesive (3M-1357), which contains approximately 16-19 wt% HAP (Table 1) including petroleum distillate and toluene and VOCs such as methyl ethyl ketone [3]. As a result, identifying a HAP-free adhesive that conforms to MMM-A-121 is a high priority for the Army.

Table 1: Products in Test Series

Product Name	**HAP (wt. %)**	**VOC (g/l)**
3M-1357 (Baseline)	16-19	490
3M-847 (Alternative)	0	0

A possible HAP free alternative product for MMM-A-121 was identified as 3M 847 Scotch-Weld™ Nitrile High Performance Rubber & Gasket Adhesive (3M-847) containing acetone (an exempt solvent) (Table 1) [4]. Laboratory testing showed that 3M Scotch-Weld™ 847 Nitrile High Performance Rubber & Gasket Adhesive (3M-847) is an acceptable replacement for MMM-A-121 adhesives. This material passed all variations of strip adhesion testing as required for the MMM-A-121 specification. .

Switching from the current baseline materials 3M Scotch-Weld™ 1357 Neoprene High Performance Contact Adhesive (3M-1357) to the HAP free adhesive replacement 3M Scotch-Weld™ 3M-847 would mean an Army wide reduction of ~1200 lbs/year of HAP and VOC emissions [5]. However, to approve 3M-847 for military use a demonstration/validation study at an actual Army facility is necessary.

2.0 TECHNICAL MANUAL PROCEDURE

2.1 UH-60 Helicopter Nose Door Seal

Procedure to install the nose door seal of a UH-60 helicopter from the technical manual (TM-1-1520-237-23) using alternative HAP free 3M-847 in place of baseline 1357 adhesive. Changes from the standard Army procedure are marked in red. There should be two separate helicopters (#1 & #2), one with each sealant for a side by side comparison.

Remove

1. Turn off all electrical power.
2. Remove nose door (WP 0188 00).
3. Remove old seal from nose door, using a nonmetallic scraper (Figure 1, Sheet 1, Detail A).
4. Remove remaining adhesive, using machinery wiping towel, Item 344, WP 1803 00, dampened with technical acetone, Item 5, WP 1803 00, and a nonmetallic scraper. **(Take photograph-1)**

Install

1. Turn off all electrical power.
   CAUTION-Do not cut into tube section of seal. Cut only the flange.
2. Fit new seal to door with spliced joints where shown (Figure 1, Sheet 1, Detail A & Detail B). To keep seal from bunching up or stretching around corners, make 30 degree to 40 degree cutouts on inner radius flange and slit outer radius flange (Figure 1, Sheet 1, Detail C).
3. Slit flange of seal (Figure 1, Sheet 2, Detail D) to prevent disbonding in bolt recess area.
4. Roughen all adhesive contact surfaces of new seal with abrasive paper, Item 208, WP 1803 00.
5. Wipe all adhesive contact areas with a clean machinery wiping towel, Item 344, WP 1803 00, dampened with technical acetone, Item 5, WP 1803 00.
6. Wipe inside seal ends and splice reinforcing tube with a clean machinery wiping towel, Item 344, WP 1803 00, dampened with technical acetone, Item 5, WP 1803 00.
7. Apply a light coat of adhesive, Item 9, WP 1803 00, to inside of seal ends and outside surface of splice reinforcing tube. **(Take photograph-2)**
8. Immediately install seal splice reinforcing tube in ends of seal and close up gap.
9. Line up seal joints on a flat surface covered with plastic sheet, Item 220, WP 1803 00, and hold for 10 to 15 minutes while adhesive sets up. **(Take photograph-3)**
10. Roughen seal splice reinforcing strip and seal joint surface with abrasive paper, Item 208, WP 1803 00.
11. Wipe roughened areas with a clean machinery wiping towel, Item 344, WP 1803 00, dampened with technical acetone, Item 5, WP 1803 00.
12. Apply adhesive, Item 9, WP 1803 00, to inside of reinforcing strip and seal splice. Install reinforcing strip over splice. Work out any gaps or blisters. **(Take photograph-4)**
13. Apply an even coat of adhesive, **3M-847**, to door and seal joining surfaces. **Allow adhesive to air dry until aggressively tacky.**

Tack is defined as the property of an adhesive that enables it to form a bond of measurable strength immediately after adhesive and adherend are brought into contact under low pressure.
Aggressive tack is defined as the property of certain adhesives, particularly non-vulcanizing rubber adhesives, to adhere on contact to themselves at a stage in the evaporation of volatile constituents, even though they seem dry to the touch [6].

14. Attach seal to door. Work out gaps, trapped air and strained areas all the way around seal installation. Remove extra adhesive with a clean machinery wiping towel, Item 344, WP 1803 00, dampened with technical acetone, Item 5, WP 1803 00. **(Take photograph-5)**
16. Mix and apply a bead of adhesive, Item 9, WP 1803 00, around the inner and outer edges of the door seal installation. Shape seal bead as shown with a beverage stirring stick, Item 300, WP 1803 00, and allow to cure at least 24 hours. **(Take photograph-6)**

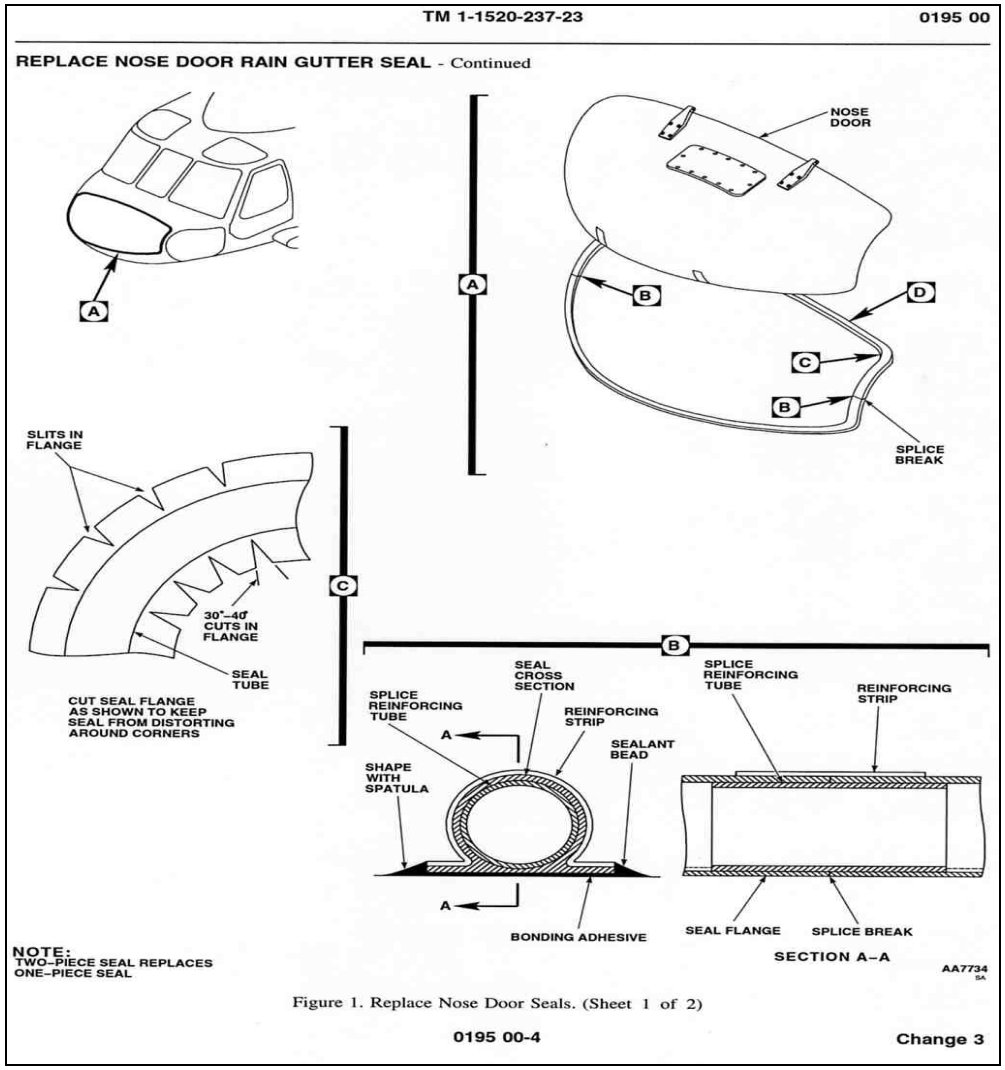

Figure 1: Replace Nose Door Seals (sheet 1 of 2)

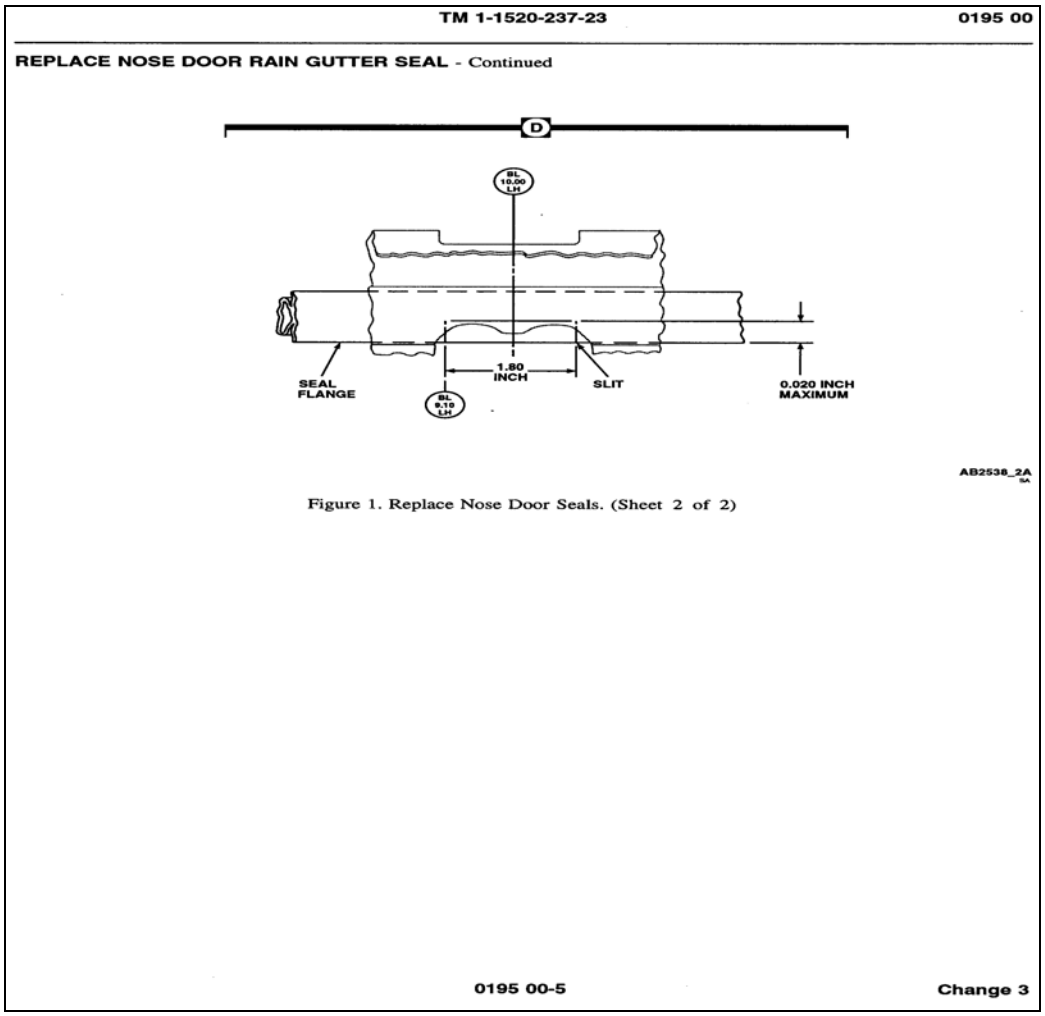

Figure 2: Replace Nose Door Seals (sheet 2 of 2)

2.2 Aviation Helmet (HGU-56/P)

Procedure for preventative maintenance and repair of aviation helmet (HGU-56/P) from technical manual (TM-1680-377-13 P) using alternative HAP free 3M-847 in place of baseline 1357 adhesive. There should be two separate helmets (#1 & #2), one with each sealant for a side by side comparison. Changes from the standard Army procedure are marked in red.

Edge Beading Repair

1. Peel the worn edge beading away from the shield or helmet.
2. Rub off old adhesive with a clean cloth. Use a razor blade if necessary.

3. Coat the edge of the shield and the edge beading with synthetic rubber adhesive **(3M-847)**. **(Take photo-1)**
4. Install the new edge beading evenly over the edge of the shield or helmet. Allow to dry.
Cut off excess edge beading with shears. **(Take photo-2)**
5. Rub off any excess adhesive with a clean cloth.

Standard Components

Figure corresponds with components listed below.

1. Helmet Shell- Protects the head from impact; provides ventilation.
2. Boom Microphone Assembly- Part of the communication assembly, which also includes earphones and a communication cord.
3. Retention Assembly- Stabilizes the helmet on the head; consists of ear-cup retaining pads, a chinstrap, and a nape strap pad with adjustable straps.
4. Ear-cups-Protect hearing by reducing noise and absorbing lateral impact.
5. Lining, Helmet, Shock (TPL)-Optimizes fit and comfort; can be heat-softened and custom-fitted if necessary.
6. Lining, Helmet, Shock (EAL) - Absorbs and reduces impact forces.
7. Dual Visor Assembly- Protects the wearer's eyes from sun glare, flash fires, ballistic spall, dust, and foreign particles; provides a mounting area for ANVIS night vision goggles.

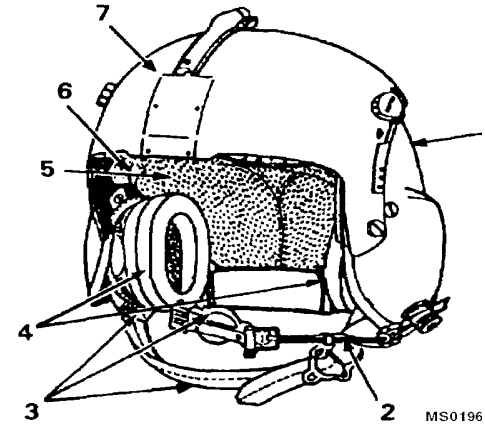

Figure 3: Helmet diagram

3.0 ITEMS OF SPECIAL IMPORTANCE

1) The proposed alternative HAP-free adhesive is 3M-847, there is no letter after the number. There are two other 847 products by 3M (847L, 847H) that are not suitable

for this dem/val. See the tech data sheet for more. Although an exempt VOC, Acetone (the primary solvent in 3M-847) is extremely flammable and toxic to the eyes, skin and respiratory tract. Wear protective gloves and goggles/face shield. Avoid repeated or prolonged contact. Use only in well ventilated areas (or use approved respirator as determined by local safety/ industrial hygiene personnel). Keep away from open flames, sparks, hot surfaces or other sources of ignition.

2) Any deviation that is made to the demo plan must first be approved by G4 (Genie Jones), ARL (Raven Toulan/John La Scala), and AED (Tammy Griffin).
3) All photographs for both UH-60 and helmet, must contain the following information:
    - Date photo was taken (every inspection interval)
    - ID # of aircraft/helmet in photo
    - Name of inspector
    - Identify the Adhesive in photo (*3M-847* or *3M-1357*)

4.0 DEMONSTRATION/VALIDATION

4.1 UH-60 Helicopter Nose Door Seal

1) Use *3M Scotch-Weld™ 1357* to perform the standard procedure for nose door seal installation on UH-60 #1.
2) Use *3M Scotch-weld™ 847* in place of *3M Scotch-Weld™ 1357* and perform the standard procedure for nose door seal installation on UH-60 #2 (section 0)
3) Compare to baseline adhesive (3M-1357) that is used to bond the nose door seal on the same day as the alternative product (3M-847)
4) Record helicopter(s) ID number being used for Dem/Val
5) Photograph the adhesive application process as it occurs, after application, at the completion of the nose door seal installation, and at all inspection time intervals for the duration of the entire Dem/Val
6) User comments on application (viscosity, spread-ability) of adhesive, color difference (brown HAP-free vs. yellow for baseline). Comment on reduced time for bonding (aggressively tacky - within 10 minutes unless very cold) vs. 30 minutes/tacky for standard adhesive.
7) Document performance of adhesives over time (see inspection check list)

4.2 Aviation Helmet Repair (HGU-56/P)

1) Use *3M Scotch-Weld™ 1357* to perform the standard procedure for helmet repair on helmet #1.
2) Use *3M Scotch-weld™ 847* in place of *3M Scotch-Weld™ 1357* and perform the standard procedure for helmet repair (section 0) on helmet #2.
3) Compare to baseline adhesive (3M-1357) that is used to repair edge beading on the same day as the alternative product (3M-847)
4) Record helmet(s) ID number being used for Dem/Val

5) Photograph the adhesive application process as it occurs, after application, at the completion of the helmet repair, and at all inspection time intervals for the duration of the entire Dem/Val
6) User comments on application (viscosity, spread-ability) of adhesive, color difference (brown HAP-free vs. yellow for baseline). Comment on reduced time for bonding (aggressively tacky - within 10 minutes unless very cold) vs. 30 minutes/tacky for standard adhesive.
7) Document performance of adhesives over time (see check list)

5.0 INSPECTION TERMS DEFINED

Operators will be inspecting the nose door seal and the helmet for the following:

1) Slippage- the movement of the adherend (rubber seal) with respect to the nose door during the bonding process
2) Deterioration- a wearing away of the adherend (rubber seal) as a result of the adhesive
3) Blistering- an elevation of the adhesive surface of varied contour and dimensions, with a void beneath it
4) Delamination- the separation or failure of the adhesive, either in the adhesive itself or at the interface between the adhesive and the adherend
    - Adhesive failure- a rupture of an adhesive bond in which the separation appears visually to be at the adhesive/adherend interface
    - Cohesive failure- a rupture of an adhesive bond, such that the separation appears to be within the adhesive
    - Substrate failure- a rupture or tare of the rubber seal at the site of the adhesive/adherend interface

1) Name & location of air field for Dem/Val-*Lowe Ft. Rucker*
2) How long to complete this dem/val? *3 months UH-60, 180 days helmet*

6.0 RESULTS REPORTING

The results will be reported according to Tables 2-19 of the dem/val plan. In addition, digital photographs of the adhesive assemblies with a label including the date of photograph, inspector's name, the particular helicopter/helmet with ID number, and the type of adhesive used (baseline or HAP-free) will be sent to ARL. The examining technician will record performance results and/or comments for each property. The examining technician(s) in conjunction with AMCOM G-4 and ARL will determine whether the HAP-free adhesive passes or fails a given property criterion. Overall, the performance of the HAP free (3M-847) should be similar to that of the current baseline (3M-1357).

7.0 CHECK LISTS FOR DEMONSTRATION/ VALIDATION

7.1 UH-60 Helicopter Nose Door Seal (tables 2-11)

Table 2: Check list of items to be inspected for the dem/val on day 1
Actual date of inspection: _____
Technician/Inspector: _____
Helicopter ID Number: _____

Table 2: Inspection check list on day 1 of UH-60 #1 application for nose door seal repaired using baseline adhesive (3M-1357).

Task	Yes/No	Comments
What is the temperature at the time of application?		
What is the humidity at the time of application?		
*All photos must contain (sec. 3.0, # 3)		
Photo of baseline 1357 applied to rubber substrate		
Photo of baseline 1357 applied to metal substrate		
Photo of bonded parts with baseline 1357		
Performance of baseline 1357 initially		

Table 3: Check list of items to be inspected for the dem/val on day 1
Actual date of inspection: _____
Technician/Inspector: _____
Helicopter ID Number: _____

Table 3: Inspection check list- on day 1 of UH-60 #2 application for nose door seal repaired with replacement adhesive (3M-847)

Task	Yes/No	Comments
What is the temperature at the time of application?		
What is the humidity at the time of application?		
Does the application of the 3M-847 feel similar to that of the baseline 1357 adhesive?		
Compare the viscosity of products (3M-847 vs. baseline 3M-1357)		
Compare the spread-ability of 3M-847 vs. baseline 1357?		
What are the benefits of the reduced time for bonding of the 3M-847 relative to the 30 minutes for baseline 1357?		
Are there any problems resulting from the reduced time for bonding of the 3M-847 relative to the 30 minutes for baseline 1357?		
*All photos must contain (sec. 3.0, # 3)		
Photograph of 3M-847 applied to rubber substrate		
Photograph of 3M-847 applied to metal substrate		
Photograph of bonded parts with 3M-847		
Performance of 3M-847 adhesive initially		

Table 4: Check list of items to be inspected for the dem/val 24 hours after application
Actual date of inspection: _____
Technician/Inspector: _____
Helicopter ID Number: _____

Table 4: Inspection check list- 24 hours after UH-60 #1 application (3M-1357)

Task	Yes/No	Comments
Did the baseline 1357 show any signs of slippage? If yes, describe and photograph		
Is there any delamination of baseline 1357? If yes, describe and photograph		
Is there any blistering of baseline 1357? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for baseline 1357? If yes, describe and photograph		
Does the nose door seal with baseline 1357 feel bonded on using manual hand pressure?		
*All-photographs for baseline 1357 (sec. 3.0, #4)		

Table 5: Check list of items to be inspected for the dem/val 24 hours after application
Actual date of inspection: _____
Technician/Inspector: _____
Helicopter ID Number: _____

Table 5: Inspection check list- 24 hours after UH-60 #2 application (3M-847)

Task	Yes/No	Comments
Did the 3M-847 have any signs of slippage**?** If yes, describe and photograph		
Is there any delamination of 3M- 847? If yes, describe and photograph		
Is there any blistering of 3M-847? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for 3M-847? If yes, describe and photograph		
Does the nose door seal with 3M-847 feel bonded on using manual hand pressure?		
* All photographs for 847 (sec. 3.0, #4)		

Table 6: Check list of items to be inspected for the dem/val 1 week after application
Actual date of inspection: _____
Technician/Inspector: _____
Helicopter ID Number: _____

Table 6: Inspection check list- 1 week after UH-60 #1 application (3M-1357)

Task	Yes/No	Comments
Did the baseline 1357 show any signs of slippage? If yes, describe and photograph		
Did the baseline 1357 show any signs of slippage? If yes, describe and photograph		
Is there any delamination of baseline 1357? If yes, describe and photograph		
Is there any blistering of baseline 1357? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for baseline 1357? If yes, describe and photograph		
Does the nose door seal with baseline 1357 feel bonded on using manual hand pressure?		
*All-photographs for baseline 1357 (sec. 3.0, #4)		

Table 7: Check list of items to be inspected for the dem/val 1 week after application
Actual date of inspection: _____
Technician/Inspector: _____
Helicopter ID Number:_____

Table 7: Inspection check list- 1week after UH-60 #2 application (3M-847)

Task	Yes/No	Comments
Did the 3M-847 have any signs of slippage**?** If yes, describe and photograph		
Is there any delamination of 3M- 847? If yes, describe and photograph		
Is there any blistering of 3M-847? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for 3M-847? If yes, describe and photograph		
Does the nose door seal with 3M-847 feel bonded on using manual hand pressure?		
*All Photographs for 847 (sec. 3.0, #4)		

Table 8: Check list of items to be inspected for the dem/val 1 month after application
Actual date of inspection: _____
Technician/Inspector: _____
Helicopter ID Number: _____

Table 8: Inspection check list- 1 month after UH-60 #1 application (3M-1357)

Task	Yes/No	Comments
Did the baseline 1357 show any signs of slippage? If yes, describe and photograph		
Did the baseline 1357 show any signs of slippage? If yes, describe and photograph		
Is there any delamination of baseline 1357? If yes, describe and photograph		
Is there any blistering of baseline 1357? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for baseline 1357? If yes, describe and photograph		
Does the nose door seal with baseline 1357 feel bonded on using manual hand pressure?		
*All-photographs for baseline 1357 (sec. 3.0, #4)		

Table 9: Check list of items to be inspected for the dem/val 1 month after application
Actual Date of Inspection: _____
Technician/Inspector: _____
Helicopter ID Number: _____

Table 9: Inspection check list- 1 month after UH-60 #2 application (3M-847)

Task	Yes/No	Comments
Did the 3M-847 have any signs of slippage**?** If yes, describe and photograph		
Is there any delamination of 3M- 847? If yes, describe and photograph		
Is there any blistering of 3M-847? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for 3M-847? If yes, describe and photograph		
Does the nose door seal with 3M-847 feel bonded on using manual hand pressure?		
*All Photographs for 847 (sec. 3.0, #4)		

Table 10: Check list of items to be inspected for the dem/val 3 months after application
Actual Date of Inspection: _____
Technician/Inspector: _____
Helicopter ID Number: _____

Table 10: Inspection check list-3 months after UH-60 #1 application (3M-1357)

Task	Yes/No	Comments
Did the baseline 1357 show any signs of slippage? If yes, describe and photograph		
Is there any delamination of baseline 1357? If yes, describe and photograph		
Is there any blistering of baseline 1357? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for baseline 1357? If yes, describe and photograph		
Does the nose door seal with baseline 1357 feel bonded on using manual hand pressure?		
*All-photographs for baseline 1357 (sec. 3.0, #4)		

Table 11: Check list of items to be inspected for the dem/val 3 months after application
Actual Date of Inspection: _____
Technician/Inspector: _____
Helicopter ID Number:_____

Table 11: Inspection check list- 3 months after UH-60 #2 application (3M-847)

Task	Yes/No	Comments
Did the 3M-847 have any signs of slippage**?** If yes, describe and photograph		
Is there any delamination of 3M- 847? If yes, describe and photograph		
Is there any blistering of 3M-847? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for 3M-847? If yes, describe and photograph		
Provide comments/observations about overall performance of replacement 3M-847 as compared to baseline 1357		
Does the nose door seal with 3M-847 feel bonded on using manual hand pressure?		
*All Photographs for 847 (sec. 3.0, #4)		

7.2 Aviation Helmet-HGU-56/P (tables 12-19)

Table 12: Check list of items to be inspected for the dem/val on day 1
Actual date of inspection: _____
Technician/Inspector: _____
Helmet ID Number: _____

Table 12: Inspection check list- on day 1 of application for helmet #1 (3M-1357)

Task	Yes/No	Comments
What is the temperature at the time of application?		
What is the humidity at the time of application?		
Performance of baseline 1357 initially		
*All photos must contain (sec. 3.0, #3)		
Photo of helmet repair area before application of 3M-1357 (after cleaning old adhesive off)		
Photo of helmet repair area immediately after application of 3M-1357		
Photo of helmet repair area after assembly of parts		

Table 13: Check list of items to be inspected for the dem/val on day 1
Actual date of inspection: _____
Technician/Inspector: _____
Helmet ID Number: _____

Table 13: Inspection check list- on day 1 of application for helmet #2 (3M-847)

Task	Yes/No	Comments
What is the temperature at the time of application?		
What is the humidity at the time of application?		
Does the application of 3M-847 feel similar to that of the baseline 1357 adhesive?		
Compare the viscosity of the products (3M-847 vs. baseline 3M-1357)		
Compare the spread-ability of (3M-847 vs. baseline 1357)		
What are the benefits of the reduced time for bonding of the 3M-847 relative to the 30 minutes for baseline1357?		
Performance of 3M-847 adhesive initially		
*All photos must contain (sec. 3.0, #3)		
Photo of helmet repair area before application of 3M-847 (after cleaning old adhesive off)		
Photo of helmet repair area immediately after application of 3M-847		
Photo of helmet repair area after assembly of parts		

Table 14: Check list of items to be inspected for the dem/val after 24 hours
Actual date of inspection: _____
Technician/inspector: _____
Helmet ID Number: _____

Table14: Inspection check list for helmet #1 after 24 hours (3M-1357)

Task	Yes/No	Comments
Did baseline 1357 show any signs of slippage?		
Is there any delamination of baseline 1357? If yes, describe and photograph		
Is there any blistering of baseline 1357? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for baseline 1357? If yes, describe and photograph		
Does the helmet edge beading with baseline 1357 feel bonded on using manual hand pressure?		
* All Photographs for baseline 1357 (sec. 3.0, #4)		

Table 15: Check list of items to be inspected for the dem/val after 24 hours
Actual date of inspection: _____
Technician/Inspector: _____
Helmet ID Number: _____

Table 15: Inspection check list for helmet #2 after 24 hours (3M-847)

Task	Yes/No	Comments
Did replacement 3M-847 show any signs of slippage?		
Is there any delamination of replacement 3M-847? If yes, describe and photograph		
Is there any blistering of replacement 3M-847? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for replacement 847? If yes, describe and photograph		
Does the helmet edge beading with replacement 3M-847 feel bonded on using manual hand pressure?		
* All Photographs for replacement 3M-847 (sec. 3.0, #4)		

Table 16: Check list of items to be inspected for the dem/val after 90 days
Actual date of inspection: _____
Technician/inspector: _____
Helmet ID Number: _____

Table 16: Inspection check list for helmet #1 after 90 days (3M-1357)

Task	Yes/No	Comments
Did baseline 1357 show any signs of slippage?		
Is there any delamination of baseline 1357? If yes, describe and photograph		
Is there any blistering of baseline 1357? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for baseline 1357? If yes, describe and photograph		
Does the helmet edge beading with baseline 1357 feel bonded on using manual hand pressure?		
* All Photographs for baseline 1357 (sec. 3.0, #4)		

Table 17: Check list of items to be inspected for the dem/val after 90 days
Actual date of inspection: _____
Technician/Inspector: _____
Helmet ID Number: _____

Table 17: Inspection check list for helmet #2 after 90 days (3M-847)

Task	Yes/No	Comments
Did replacement 3M-847 show any signs of slippage?		
Is there any delamination of replacement 3M-847? If yes, describe and photograph		
Is there any blistering of replacement 3M-847? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for replacement 847? If yes, describe and photograph		
Does the helmet edge beading with replacement 3M-847 feel bonded on using manual hand pressure?		
* All Photographs for replacement 3M-847 (sec. 3.0, #4)		

Table 18: Check list of items to be inspected for the dem/val after 180 days
Actual date of inspection: _____
Technician/inspector: _____
Helmet ID Number: _____

Table 18: Inspection check list for helmet #1 after 180 days (3M-1357)

Task	Yes/No	Comments
Did baseline 1357 show any signs of slippage?		
Is there any delamination of baseline 1357? If yes, describe and photograph		
Is there any blistering of baseline 1357? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for baseline 1357? If yes, describe and photograph		
Does the helmet edge beading with baseline 1357 feel bonded on using manual hand pressure?		
* All Photographs for baseline 1357 (sec. 3.0, #4)		

Table 19: Check list of items to be inspected for the dem/val after 180 days
Actual date of inspection: _____
Technician/Inspector: _____
Helmet ID Number: _____

Table 19: Inspection check list for helmet #2 after 180 days (3M-847)

Task	Yes/No	Comments
Did replacement 3M-847 show any signs of slippage?		
Is there any delamination of replacement 3M-847? If yes, describe and photograph		
Is there any blistering of replacement 3M-847? If yes, describe and photograph		
Is there any deterioration/ failure of the adhesive bond for replacement 847? If yes, describe and photograph		
Does the helmet edge beading with replacement 3M-847 feel bonded on using manual hand pressure?		
Provide comments/observations about overall performance of 3M-847 as compared to baseline 1357.		
* All Photos for replacement 3M-847 (sec. 3.0, #4)		

8.0 References

[1]. Concurrent Technologies Corporation, "NESHAP Requirements Assessment for Miscellaneous Coatings, Adhesives, Sealers, Etc.," *Final Report, Sustainable Paint Operations for the Total Army*, Johnstown, PA, 2004.

[2]. Vallone, J, "NESHAP Requirements Assessment for Miscellaneous Coatings, Adhesives, Sealers, Etc.," *Final Report, Sustainable Painting Operations for the Total Army*, Johnstown, PA, 2004.

[3] Scotch-Weld™ Neoprene High Performance Contact Adhesive 1357 MSDS, 3M Company, St. Paul, MN.

[4] Scotch-Weld™ Nitrile High Performance Rubber & Gasket Adhesive 847 MSDS, 3M Company, St. Paul MN.

[5]. Concurrent Technologies Corporation, "Final Applied Performance Document," *Sustainable Painting Operations for the Total Army*, Johnstown, PA, 2008.

[6]. ASTM 907-05 "Standard Terminology of Adhesives", West Conshohocken, PA, May 2005.

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Appendix B. Demonstration/Validation MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel HAP-Free Replacement [1]

This appendix appears in its original form, without editorial change.

[1]Toulan, F. R. Demonstration Validation Plan (Draft II) for MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel HAP-Free Replacement. U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, June 2009, abridged.

Demonstration/Validation Plan II for MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel HAP-Free Replacement was nearly identical to Demonstration/Validation Plan (Original). The following list the specific changes that were made in Demonstration/Validation Plan II:

Baseline material for the model #HGU-56/P aviation helmet was changed from *3M Scotch-Weld™ 1357* (3M-1357) to *Clifton E-1293*. All callouts to *3M-1357* for the aviation helmet only were replaced with *Clifton E-1293*.

Details of Clifton E-1293 were added to Table 1 to include HAP content of 50-60 wt% and VOC content of 640-680 g/l.

In the procedure for installation of the UH-60 nose door seal (pg 2 in original dem/val plan), the procedure was changed in two spots:

After step 7 of the original procedure, the following step was added:

Apply a second coat of adhesive (same as #7) and then immediately install seal splice reinforcing tube in ends of seal and close up gap. (Take photo-3**)**

After step 13 of the original procedure (step 14 of dem/val plan II), the following step (step 15 of dem/val plan II) was added:

Apply a <u>second</u> even coat of adhesive, to door and seal joining surfaces while product is still aggressively tacky. (Take photo-7, before bonding surfaces together)

<u>Note: Steps 14 & 15 must be followed exactly to achieve a sufficient bond. Both adhesives (3M-1357 and 3M-847) require a second coat on every surface.</u>

In the procedure for repair of the aviation helmet (pg 4-5 in original dem/val plan), the procedure was changed:

After step 3 of the original procedure, the following step was added:

Apply a second coat of adhesive (3M-847) to both surfaces and join when adhesive is aggressively tacky. (Take photo-2)

Step 6 of Section 4.1 of the original plan, the following step was changed:

Original: User comments on application (viscosity, spread-ability) of adhesive, color difference (brown HAP-free vs. yellow for baseline). Comment on reduced time for bonding (aggressively tacky - within 10 minutes unless very cold) vs. 30 minutes/tacky for standard adhesive.

Dem/Val Plan II: User comments on application (viscosity, spread-ability) of adhesive, color difference (brown HAP-free vs. blackish/green for baseline). **Note: the second coat required for 3M-847 and 3M-1357 is on both surfaces. Comment on reduced time for bonding (aggressively tacky - within 10 minutes unless very cold) for 3M-847 vs. 30 minutes/tacky for standard adhesive 3M-1357.**

Step 2 of Section 4.2 of the original plan, the following step was changed:

Original: Use *3M Scotch-weld™ 847* in place of *3M Scotch-Weld™ 1357* and perform the standard procedure for helmet repair (section 2.2) on helmet #2.

Dem/Val Plan II: Use *3M Scotch-weld™ 847* in place of *E-1293* and perform the standard procedure for helmet repair (section 2.2) on helmet #2. **Note: the second coat required for 3M-847 is on both surfaces.**

The last sentence of Section 6.0 was changed:
Original: Overall, the performance of the HAP free (3M-847) should be similar to that of the current baseline (3M-1357).
Dem/Val Plan II: Overall, the performance of the HAP free (3M-847) should be similar to that of the current baseline (E-1293 or 3M-157).

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Appendix C. Tasker No. 70900 Memorandum [1]

This appendix appears in its original form, without editorial change.

[1] Kane, M. J. Memorandum for AMSAM-EN-EV TTS Tasker No. 70900; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 11 June 2009.

RDMR-AEF

11 JUN 2009

MEMORANDUM FOR AMSAM-EN-EV (Mr. Glenn Williams)

SUBJECT: Review of Demonstration/Validation Plan for Scotch-Weld 847 as an Alternative to Currently Used MMM-A-121 Adhesives, TTS 70900

1. References:

   a. TTS Tasker #70900, dated 29 May 2009, subject as above.

   b. Army Research Laboratory (ARL), Demonstration/Validation Plan II (draft) for MMM-A-121 Federal Specification, Adhesive, Bonding Vulcanized Synthetic Rubber to Steel, HAP Free Replacement, dated 20 May 2009.

   c. Technical Data Sheet, "3M Scotch-Weld Nitrile high Performance Rubber & Gasket Adhesive", dated November 2007.

2. We reviewed and approve the subject Demonstration/Validation Plan (ref. 1.b) from a materials engineering point of view. The revised plan includes instruction to apply two coats of 3M Scotch-Weld 847 prior to bonding when working with porous surfaces. These instructions are validated by the product's technical data sheet (ref. 1.c).

3. The point of contact for this action is Benjamin T. Beyer, Wyle Laboratories, Inc., (256) 313-6395, ben.beyer@us.army.mil.

TTS 70900

for MICHAEL J. KANE, Ph.D.
Chief, Materials Branch
Structures and Materials Division

Originator BB 6/10/09
Team Leader [illegible] 11 Jun 09
PSA Rev
Br/Div Chief
AED Log/Rev

Coordination: MG for CF 6/10/09
Morgan, A Stanley Co.

AMSRD-AMR-AE-F-M

20 FEB 2009

MEMORANDUM FOR AMSRD-AMR-AE-U (Mr. Carl Pierce)

SUBJECT: Adhesive Demo/Validation Plan for MMM-A-121 Federal Specification, Adhesive, Bonding Vulcanized Synthetic Rubber to Steel, 3M Scotch-Weld 847, Hazardous Air Pollutant (HAP) free alternative to 3M Scotch-Weld 1357

TTS 66547

1. References:

   a. Task Tracking Number 66547, dated 29 January 2009, subject as above;

   b. Army Research Laboratory (ARL), Demonstration/Validation Plan (draft 4) for MMM-A-121 Federal Specification, Adhesive, Bonding Vulcanized Synthetic Rubber to Steel, HAP Free Replacement; and

   c. ARL Draft Technical Report: MMM-A-121 Federal Specification Adhesive, Bonding Vulcanized Synthetic Rubber to Steel, HAP Free Replacement.

2. We conducted a review of the subject Demo/Validation Plan (ref. 1.b.) from a materials engineering point of view, and it is approved. Comments and recommendations are provided:

   a. Test results from ARL (ref. 1.c.) indicate that 3M Scotch-Weld 847 meets the performance requirements of MMM-A-121.

   b. It is noted that the 3M Scotch-Weld 847 Technical Data Sheet documents significant loss of properties at temperatures approaching 180°F, and shows no results below 30°F. It is recommended that performance tests also be performed at operational temperature extremes.

3. The point of contact for this action is Mr. Christopher Flick, Morgan, A Stanley Company, 256-313-3161.

MICHAEL J. KANE, Ph.D.
Chief, Materials Branch
Structures and Materials Division

Originator CDF 18 February 2009
Team Leader [illegible] 20 Feb 2009
PSA Rev
Br/Div Chief
AED Log/Rev

Coordination: CDF 18 February 2009
Morgan, A Stanley Co.

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List of Symbols, Abbreviations, and Acronyms

ACLC	U.S. Army Aviation Center Logistics Command
AMCOM	U.S. Army Aviation and Missile Command
ARL	U.S. Army Research Laboratory
EPA	Environmental Protection Agency
HAP	hazardous air pollutant
MEK	methyl ethyl ketone
NDS	nose door seal
QPL	qualified product list
SBR	styrene-butadiene rubber
VOC	volatile organic compound

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